POINT BONITA LIGHTHOUSE BRIDGE – RG 2858

GOLDEN GATE NATIONAL RECREATION AREA, CALIFORNIA

FHWA PROJECT – CA NPS GOGA 433(1)

STRUCTURE SELECTION REPORT

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PROJECT DESCRIPTION

In 1954, the U.S. Coast Guard built a suspension footbridge to access the Point Bonita Lighthouse on the outer northwestern point overlooking San Francisco Bay. Since then the bridge has undergone at least two major renovations, including replacement of principal components of the bridge. The bridge is owned by the Coast Guard and maintained by the National Park Service (NPS). Point Bonita is in the Golden Gate National Recreation Area.

The NPS has determined that the Point Bonita Lighthouse Bridge should be replaced.

This report summarizes the existing conditions, technical issues, and alternatives for the replacement bridge.

HISTORICAL BACKGROUND

At the start of the California Gold Rush in 1848, San Francisco became the main port for gold seekers from around the globe. To guide ships safely into the bay, a system of lighthouses was developed and operated by the United States Lighthouse Service. In 1855, a lighthouse was constructed at Point Bonita along the northern entrance to the San Francisco Bay, on a high ridge nearly 300 feet above the water.[1] The lighthouse was accessible only by traversing a treacherous wooden platform suspended from a 200-foot-high cliff or, after 1876, by passing through a tunnel that had been hand-hewn through the rock.[2, 3]

The original lighthouse was relocated to its current location in 1877. [1] In 1939, ownership was transferred to the United States Coast Guard.[4] In 1940, when a large section of the bluff just east of the lighthouse sloughed into the ocean, blocking access to the lighthouse, the Coast Guard built a wooden causeway to bridge the gap and began planning for the Point Bonita Lighthouse Bridge, which was built in 1954. This is the bridge that still stands today.[5]

In the 1960s, the Coast Guard closed the lighthouse to the public. In 1972, the Golden Gate National Recreation Area (GGNRA) was established, and in 1984 the station was re-opened for public tours by the NPS. While it is still owned by the Coast Guard, the bridge is maintained by the NPS as part of the GGNRA.[6]

In 1991, the Point Bonita Light Station was entered into the National Register of Historic Places (NRHP). The nomination form established its period of significance as extending from 1855 to 1940; because the suspension bridge was constructed in 1954, it was determined to be a non-contributing structure.[7] However, in a Cultural Landscapes Inventory (CLI) completed in 2005, the Point Bonita Historic District's period of significance was extended to 1966 and the suspension bridge was determined to be a contributing structure.[8]

EXISTING CONDITIONS

Bridge Configuration and Condition

The existing structure is a two-hinged suspension bridge with asymmetrical straight backstays. The main span is 156 feet between the towers. The clear distance between the handrails is 4 feet, 6 inches. The towers, stiffening truss, and decking are all made of timber. Originally, the span was supported by two main cables consisting of 1 3/8–inch diameter galvanized steel bridge cable (bridge rope) with ¾-inch diameter galvanized steel rod suspenders; the wind cable system consisted of ¾-inch–diameter galvanized steel bridge cable with ½-inch–diameter galvanized steel suspenders. The lateral bracing system consisted of galvanized steel angles. The main cables and wind cables are anchored by large concrete gravity blocks. At the east end the wind cables are each anchored in individual blocks. At the west end, the wind cables share the same anchor block with the main cables.[9]

In 1977, as a temporary repair, a secondary wind cable system was installed adjacent to the existing wind cable system.[10] In 1979, the bridge underwent a major rehabilitation. The main cables and the wind cables were both replaced with 1 1/4-inch–diameter galvanized steel bridge strand. The suspender rods were replaced with 7/8-inch–diameter galvanized steel rods. The wind suspender cables were replaced with ½-inch–diameter galvanized utility grade strand. The lateral bracing system was replaced in kind. In addition, most of the hardware was replaced including cable bands, anchor sockets, saddles, clevis loops, top chord straps, chaffing plates, tower leg brackets, and all bolts.[11]

In 1987, the wind cable suspenders were replaced again. The replacement suspenders consisted of 5/8-inch–diameter stainless steel cables.[12] In 1990, the bridge was repainted, and in 1991 the main cables and the wind cables were replaced again with 1 1/4-inch–diameter galvanized steel bridge strand. The cable anchor assemblies were also replaced at that time.[13]

The last maintenance performed on the bridge was in 1998, when the bridge was repainted. According to the 2007 bridge inspection report, the deterioration of the paint system has resulted in an accelerated rate of corrosion of the suspension and wind cables and moderate to severe rusting of cable attachment hardware with minor to moderate section loss throughout. Some of the wind cable hardware has extensive section loss. Additionally, the truss and tower timber members are showing widespread moderate-to-severe decay as a result of high moisture content.[14]

In recent years, access to the bridge has been limited to only two people at a time. In July 2008, the bridge was closed to all public traffic due to the severe deterioration of cables and associated hardware. The Coast Guard made temporary repairs and re-opened the bridge, but has had to maintain the two-people-at-a-time limit. The bridge has been recommended for replacement as soon as plans can be prepared and funding secured.

Site Access

Construction staging and access to the bridge site will be a significant challenge during the construction of a new bridge. The only land access to the site is by way of a narrow ½-mile-long trail that is fairly steep in spots. There is a public parking area at the trail head, which would likely serve as the primary parking area for workers as well as the main construction staging area. Small, single-rear-axle work vehicles will be able to traverse the first half of the trail to deliver materials closer to the project site, but there is only a very small area to park or turn a vehicle around. Access beyond this point is limited by the tunnel. A

West tunnel portal and narrow trail.

locking steel door at the east tunnel portal provides an opening of about 6 feet tall by 4 feet wide. The arched tunnel is only slightly larger than the doorway: about 6 feet, 6 inches high, 4 feet wide at the top, and 6 feet wide at the bottom. West of the tunnel, the trail is even narrower, with sharp curves, and is further limited by two newer pedestrian bridges with a clear width of about 4 feet, 6 inches. The east end of the suspension bridge could serve as a secondary construction staging area with a maximum area available of about 3,000 square feet.

The steep rocky cliffs and dangerous surf make access by water virtually impossible. Any construction materials not transportable along the trail will likely have to be dropped in by helicopter cranes.

Note showing steep rocky cliffs and narrow isthmus under bridge.

Once the bridge is removed, access to the far (west) side is obviously more difficult. However, the bridge doesn't span over water but over a depressed, narrow, knife edge isthmus, with near vertical cliffs on either side. A protected path of ladders and walkways could be constructed, down - across the isthmus - and up the other side. Workers could use this walkway to get back and forth but equipment would need to be brought to the west side prior to removal of the existing bridge or brought in by helicopter.

Construction of small suspension pedestrian bridges can be accomplished with light equipment that is movable by manual labor only. All components of the towers and suspended span are relatively light. Although labor intensive, a suspension bridge is a good solution when vehicular access is limited.

The contractor's operations and equipment will need to occupy the small parking area at the tunnel and the available staging area at the east end of the bridge. Also, the contractor's workers will be transporting equipment and materials along the narrow path. From a safety standpoint, visitors should not be permitted to visit Point Bonita during working hours. Visitors could be permitted on weekends but the contractor would need to clean up and secure the site at the end of every week. This would reduce his available work hours, increase his risk and drive up the project cost.

Geology

A preliminary geotechnical reconnaissance of the site was conducted on July 1, 2008, by FHWA Central Federal Lands Highway Division staff. The point consists of Mesozoic diabase and pillow basalt overlaid by sandstone and shale. The eastern bridge abutment is founded on erodible sandstone with some minor shales. The western abutment is on similar but harder sands, which exhibit more quartz cementation.

All foundation materials present at the site are susceptible to erosion, although the weathering processes appear to be fairly slow, based on review of coastal erosion photos dating back to the early 1970s. Structural mapping was not performed during the reconnaissance so the potential for sudden failures during or after construction has yet to be evaluated. The foundation materials are thought to be suitable for additional stabilization measures such as rock bolting and/or grouting. Visual inspection revealed no signs of recent rock mass failure adjacent to the bridge.[15]

There has been a long history of coastal erosion leading to landslides all along the point. In March 1971, the commander of the 12th Coast Guard District reported that "the entire face of the cliff along the trail to the lighthouse was sliding into the sea."[16]

In 1976, a geotechnical investigation was performed along the point to assess a number of slide areas. The text of the report was not readily available; however, a set of drawings from the investigation was available. In the area of the bridge, the plans included a boring at each main cable anchor block as well as a travel-time curve for an area near the east abutment. The boring at the east anchor shows reddish brown greenstone, severely weathered with very closely spaced fractures and joints, that crumbles easily directly beneath the anchor block. The greenstone transitions from soft to moderately hard to medium hard, with angular fragments to a depth of about 38', where the greenstone becomes hard with angular fragments. The boring at the west anchor block shows greenstone, mottled light gray and green, hard with closely spaced fractures, iron oxide stains on joint and fracture surfaces directly beneath the anchor block. The fractures dip at 20 to 40 degrees.[17]

A more detailed geotechnical investigation will need to be conducted in conjunction with the final design.

DESIGN PARAMETERS AND CRITERIA

Complete Replacement

Based on previous field inspections, the National Park Service (NPS) has determined that the Point Bonita Lighthouse Bridge should be replaced. The bridge was built in 1954 and has undergone at least two major rehabilitations, one in 1979 and one in 1991. Currently, only two people are permitted on the bridge at a time. The main cables, suspenders, stiffening truss, wind system, towers and connections are all in poor condition. Rehabilitation does not appear to be a reasonable option and has not been considered. The bridge will be completely replaced; however, reuse of parts of the foundations will be considered in this report.

General Bridge Type and Appearance

The Point Bonita Light Station is on the National Register of Historic Places (NRHP). The suspension bridge, which was built much later than the lighthouse, was recently added as a contributing structure. (See Historical Background section of this report.) The NPS is handling the environmental permitting associated with the bridge replacement project, including any historic evaluation. Although that work has not yet been completed, the NPS gave direction regarding the bridge replacement at an August 19, 2008, Field Inspection Review. That direction is summarized below.

- The replacement bridge should have similar look as the existing bridge. The bridge should be a suspension bridge with A-shaped towers. However, different materials should be considered, where warranted. For example, steel could be used in lieu of timber for the trusses or towers. Materials and details should be chosen to minimize future maintenance.
- Replace the bridge with a similar footprint. Currently, the bridge is 4½ feet wide.

Americans With Disabilities Act (ADA) requirements were discussed. Access to the bridge, through the tunnel and along the path, is very limited. This, coupled with the fact that approach structure widths are no greater than 4½ feet, gives little reason for providing greater widths for the replacement structure. Therefore, a clear width of 4½ feet will be provided for the new bridge

Design Specifications

Where applicable, the design shall conform to:

- AASHTO Guide Specifications for the Design of Pedestrian Bridges
- AASHTO LRFD Bridge Design Specifications LRFD
- Other material and design specifications as appropriate for the selected materials

Design Loading

Live Load

Design will use 85 pounds per square foot with applicable reductions as outlined in section 1.2.1 of the AASHTO Guide Specifications for the Design of Pedestrian Bridges. Because the bridge is less than 6 feet wide, it will not be designed for any maintenance vehicle loading. However, the bridge deck will be designed for a 1,000-pound point load to account for any larger items that may need to be carried to the lighthouse.

Live Load Deflection

The AASHTO Guide Specifications for the Design of Pedestrian Bridges limits live load deflection to L/500 of the design span. This provides a feeling of security and stability for the pedestrian. This may not be practical or even desirable for a cable pedestrian bridge, which by very nature is flexible. In fact, the NPS reports that the pedestrians say they like the movement of the bridge and see it as part of the adventure associated with a cable suspension trail bridge. Cable-supported pedestrian bridges are typically designed for greater live load deflections, often around L/360. Other specifications allow for deflections between L/180 and L/360. Live load deflections will be evaluated during final design.

Wind Loading

Some of the highest winds along the Pacific Coast have occurred just north of Point Bonita. At Point Reyes, the highest recorded wind speed was 133 mph — a measurement taken just before the meter broke. The structure and wind cable system will be designed for wind in accordance with AASHTO LRFD Section 3.8, with wind velocities taken from ASCE 7-88.

Earthquake Analysis and Loading

The project site is in one of the most seismically active areas in the United States. In fact, the San Andreas Fault is only a few miles off the coast. Although difficult to analyze, seismic loads should be relatively easy to accommodate for this small, light, pedestrian bridge. The seismic loads will have to be carefully evaluated, analyzed, and accommodated during final design.

Other Design Considerations

- The GGNRA would like to maintain access to the east end of the bridge (at least on weekends) during construction, to allow viewing of the lighthouse by the public.
- Power and communications lines currently cross the bridge. These must be maintained.
- The bridge and associated components should have at least a 50-year life with normal maintenance for the given environment.

PROPOSED STRUCTURE CONFIGURATION

As established in the previous section, the goal of this project is to replace the existing bridge with a similar-looking bridge to maintain the historic character of the site. Therefore, barring any unforeseen technical difficulties, the bridge will be replaced with a similar configuration. Several conditions need to be evaluated and could result in modifications to the configuration of the new bridge. These issues are described below.

General Layout

The existing bridge stands on top of the narrow peninsula that forms Point Bonita. The bridge spans 156 feet over the gap that was created when a piece of the cliff face slid into the sea in 1939. Due to the tight site constraints, the bridge has unsymmetrical backstays.

The east backstay is 33.16 feet long and forms an angle of 53 degrees from horizontal. This is less than ideal; however, the anchorage block is pushed right to the east edge of the bluff. The west backstay is closer to ideal, at 55 feet long and forming an angle of 21.5 degrees from horizontal. The west anchorage block also sits right at the edge of the cliffs.

The east wind anchors are splayed out and also sit near the edges of the cliffs. There was no room to splay the west wind anchors, so the west wind cables were bent around struts and anchored back at the west anchorage block.

There is very little room to make any improvements in the overall bridge geometry. It would be desirable to realign the bridge slightly to eliminate an awkward kink in the footpath on the west side. However, a detailed survey and geotechnical investigation would need to proceed any proposed realignment and it is doubtful that the situation could be much improved. At this time we have assumed that the bridge alignment will not be modified.

Geologic Stability

Due to the constraints of the site, the bridge towers and anchorages were constructed very close to the edges of the cliffs. The proximity of the cliffs and the potential for erosion at the cliff edges presents obvious concern with regard to the proposed bridge. Evaluation of the potential risk from erosion at the cliff edges is beyond the scope of this report. Very little opportunity exists to move the piers or anchorages further from the cliff faces. A more detailed geotechnical investigation will need to be conducted in conjunction with the final design.

Suspension System Geometry

The existing cable geometry (156-foot span, 14-foot sag) can support the proposed loads using 1 ½-inch–diameter galvanized bridge strand main cables. Due to the site constraints described above, the proposed bridge will have unsymmetrical backstays similar to those on the existing bridge. Increasing the tower height would reduce the cable loads.

Anchorage Blocks

The existing cable anchorage blocks appear to be in good condition; however, they are considerably undersized to carry the proposed loads of the new bridge. Although the design loads were not recorded on the 1954 design plans, there is clear evidence that the original design loads were significantly less than those proposed for the replacement bridge (85 PSF with appropriate reduction factors). The 1954 design plans specify the main cables to be 1 3/8 inches in diameter (6 x 7) galvanized bridge cable with a breaking strength of 87.8 tons. These cables would not support the proposed loads for the replacement bridge with an appropriate factor of safety. The 1979 retrofit and the 1991 retrofit both used 1 ¼-inch–diameter galvanized bridge strands with higher ultimate strength than the original 1954 cables; however, the loads are limited by the sizes of the anchorage blocks. The 1991 retrofit plans indicated that "the maximum allowable load on the bridge is a uniform live load of 4 PSF or a concentrated load of 950 pounds." This is not adequate for public pedestrian use.

The existing concrete anchorage blocks will need to be removed and replaced with considerably larger, heavier blocks. Alternatively, the existing blocks could be drilled and held down with high-strength rock anchors. Increasing the tower height would also slightly reduce the horizontal loads on the anchorage blocks. These alternatives should be investigated in more detail during final design.

Wind Cables

Horizontal wind cables restrain the flexible bridge against wind loads. The proposed bridge will use a similar wind cable system. The existing wind cables are buried between the towers and the anchorages. This leads to corrosion of the wind cables and makes them impractical to inspect. They have been replaced three times since 1954. Opportunities to improve the wind cable system should be explored during final design.

Tower Foundations

The existing pier foundations appear to be in good condition. They are spread footings bearing directly on rock. The pier foundations should be able to accommodate the geometry of the new towers. It is proposed to reuse the existing pier foundations.

Towers

The existing towers are A-shaped, 18.4 feet tall, and made of solid timbers and bracing members. The proposed towers will have a similar look.

Truss

The proposed bridge will have a combined stiffening truss and railing to mimic the look of the existing bridge.

Deck

The proposed bridge will have a 4 ½-feet-wide deck, as described in the criteria section.

PROPOSED STRUCTURAL COMPONENTS

In addition to being located in a marine environment, the bridge is exposed to heavy salt-laden fog for extended periods every year. This combination is highly corrosive, especially to any metal components. This is why salt fog chamber tests have been used for more than 90 years as accelerated tests to determine the performance of materials and coatings in a corrosive environment. Many of the metal components on the bridge have already been replaced twice and are in need of replacement again. Surprisingly, the timber members are the only portions of the bridge that are still original.

Due to this environment and its harsh effects, the selection of materials for the various components of the replacement bridge is one the most important decisions to be made. As such, a very detailed discussion of available materials is warranted and follows below.

Main Suspension Cables

Galvanized Wire

The use of iron wire for suspension bridge cables originated almost simultaneously and independently in the United States, England, and France. The earliest attempts were in footbridges in the U.S. and Scotland, constructed around 1816. In 1822, five brothers from the Séguin family in France developed a more deliberate, organized, and scientific approach to designing and constructing wire-cable suspension bridges. It was Charles Ellet, Jr., and John Augustus Roebling who later brought these new developments to America. Roebling's Cincinnati-Covington Bridge, completed in 1866, was the last major suspension bridge constructed with wrought-iron wires. At this point, commercially available and stronger steel wire began to be used. In the design of the Brooklyn Bridge, Roebling first used steel wire with a galvanized zinc coating.[18] From the Brooklyn Bridge (completed in 1883) to the Golden Gate Bridge (1937) to the Akashi-Kaikyo Bridge (1998) to bridges being built today, galvanized zinc coated wire continues to be the material of choice for suspension bridge cables.

When exposed to corrosive attacks, the galvanized coating will corrode first and the resulting electrochemical reaction will protect the steel wire until a large area of the zinc coating is consumed. Once the zinc coating is consumed, the steel wire itself will begin to corrode. There are three classes of galvanized coating: Class A (1.0 oz / sq ft), Class B (2.0 oz / sq ft), and Class C (3.0 oz / sq ft). The American Society for Testing and Materials (ASTM) has conducted a few studies on the corrosion rates of the different classes of galvanized coatings. One study indicated that, for Class A galvanization, the life of the protective coating was 24 years in a rural atmosphere and 7 years in a marine atmosphere. The corresponding life for Class B galvanization was 40 years and 12 years, respectively. No corresponding tests were made for Class C galvanization.[19] Based on another study that showed that the loss of zinc per year was linear, it may be estimated that Class C galvanization might have a corresponding life of about 17 years in a marine environment.

For typical suspension pedestrian bridges, the main cables each typically consist of one or two prefabricated bridge strands or bridge ropes. Bridge strand is used most often and is stronger than bridge rope for a given diameter. The existing Point Bonita Bridge utilized a 1 3/8-inch–diameter Class A galvanized bridge rope for each main cable when it was first constructed. In the two subsequent cable replacements, 1 ¼-inch–diameter galvanized bridge strand was used.

While the class of galvanizing was not shown on the plans, it is suspected that Class A was utilized. The existing main cables show signs of moderate-to-severe rusting with minor-to-moderate section loss. On average, the three different main cables that have been installed on the bridge over its life have lasted about 18 years each. We would estimate that bridge strand with Class C galvanization and no other protection would last 30 years or more in the Point Bonita environment.

Similar to galvanization is the Galfan® coating system. Galfan® is the trade name for an alloy product containing 95 percent zinc, roughly 5 percent aluminum and small amounts of mischmetal. It was developed by the International Lead Zinc Research Organization in 1981, which recently transferred its ownership rights to the Galfan Technology Center, located at the University of Pittsburgh Applied Research Center.[20] This type strand is often used for guys, messengers, span wires, and similar devices. Galfan® is applied in a hot-dip bath similar to hot-dip galvanizing. It provides improved corrosion resistance over conventional galvanized coating by combining the passive corrosion inhibition of aluminum oxidation with the active and passive effects of zinc. Strand composed of Galfan® coated wire will last approximately 40 percent longer than strand composed of galvanized wires with a Class C coating.[21] We would estimate that bridge strand with Galfan® coated wire and no other protection would last 40 years or more in the Point Bonita environment. However, Galfan® coated strand costs between two to three times as much as traditional galvanized strand.

ASTM Standard A855 was developed for zinc-aluminum-mischmetal alloy-coated steel wire strand. In addition to Galfan®, there are other very similar products that provide comparable levels of protection.

Galvanized Wire with Corrosion Inhibitors

Applying corrosion inhibitors to galvanized wire has been shown to significantly reduce the rate of corrosion. Corrosion inhibitors can be applied to the individual wires as the strands are being manufactured or applied to the completed strand—or both. Corrosion inhibitors come in many forms, including paints, oils, greases, and pastes.[22]

Red lead paste has been used on many of the major suspension bridges, including all three bridges listed above. Zinc paste can be used as an alternative to red lead paste, and was used in the new Tacoma Narrows Bridge. Similar to pastes are greases and oils. The Grignard Company has developed a number of greases and oils to improve the corrosion resistance of galvanized wire and strand. Gri-Kote Z-Complex 2C is a corrosion-resistant, multiple-barrier grease that incorporates a combination of zinc oxide and zinc dust in a blend of vegetable oil with additional corrosion inhibitors. It increases the life of the strand by protecting the wires as a sacrificial anode and repelling water. Another Grignard product is Prelube 19. Prelube 19 is a linseed oil-based compound with rust inhibitors that penetrates and forms a corrosion protecting film on the wires. It also acts to lubricate the wires, thus reducing wear of the galvanized coating.[23] Class A galvanized wires with corrosion inhibiting coatings provide about the same protection as Class C galvanization. Pastes, greases, and oils are all typically applied to the completed cable prior to installing a secondary wrapping system. For individual cables without a secondary wrapping, some of these coatings can be applied to the inner wires only to eliminate the exposed “greasy” surface. However, over time these coatings have a tendency to “leak out” of the bottom of the cable.[21]

Paints are also a type of corrosion inhibitor. The use of red lead as a pigment dates back at least to ancient Rome. In the modern era, it was combined with linseed oil as a thick, corrosion-resistant paint. Red lead paint used to be the paint of choice for bridges and was the original paint system utilized on the Golden Gate Bridge. In the 1940s, a growing concern with the danger of lead poisoning associated with exposure to lead paint, especially to children, led to a federal ban on paint with total lead content of more than 0.06 percent in 1978.[24] Since then, dozens if not hundreds of different paint systems have been developed for bridges and other outdoor structures. Not surprisingly, the majority of today's paint systems include some form of zinc.

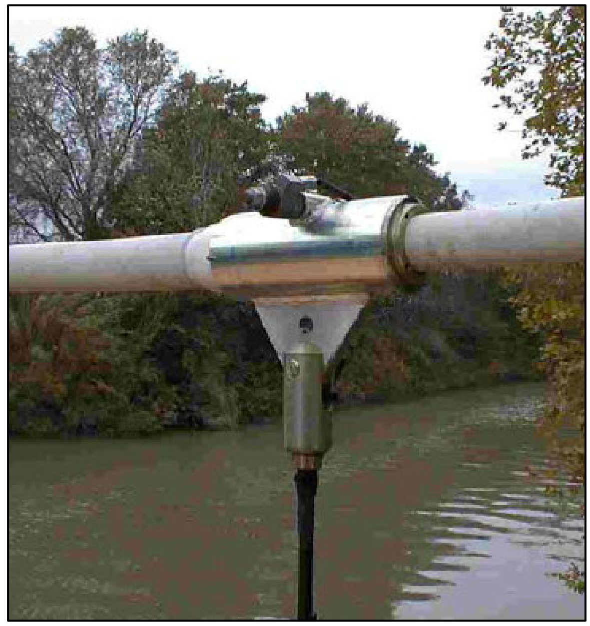
Noxyde is a rust-preventive, water-based acrylic elastomeric coating developed by Martin Mathys of Belgium and distributed in the U.S. by Rust-oleum. Noxyde is highly elastic, with 200 percent elongation, and adheres well to galvanized metal. This combination makes it a great paint to protect galvanized bridge cables and suspenders, which must remain flexible. Noxyde is so flexible that it can be shop-applied to a cable that can then be rolled onto a spool without compromising the paint. Noxyde is also UV resistant and has a proven 20-year service life in highly corrosive industrial applications. The main cables, the suspenders, and the associated hardware for the new Tacoma Narrows Bridge are painted with Noxyde. In addition, many recent main cable rehabilitation projects have specified this paint system, including the Brooklyn Bridge, which is slated to be repainted next year.[25] We would estimate that bridge strand with Class C galvanization and a Noxyde paint system (or similar) should last 50 years or more in the Point Bonita environment. Repainting would extend the life even further.

Galvanized Wire with Secondary Wrapping

In addition to some type of corrosion inhibitor, the main cables of major suspension bridges including the ones listed above also have at least one additional cable wrapping system. The Golden Gate Bridge has a Class A galvanized wire wrapping system laid over red lead paste around the main cables. The wire wrapping system was originally painted with a red lead primer and a linseed oil enamel top coat. The first recoating of the main cables began in 2007, after 70 years.[26] As an example of a more modern protection system, the Akashi-Kaikyo Bridge utilizes prefabricated strands made with Class A galvanized wire. Prelube 19 was applied to the wire during strand fabrication. The completed main cables were then wrapped in galvanized wire bedded in red lead paste. The wire wrapping was then covered with a neoprene-hypalon wrapping system, which consists of a layer of liquid neoprene followed by a sheet of neoprene spirally wrapped around the cable, followed with two coats of hypalon paint.[27]

While an elaborate protection system like the one described above is suitable and warranted for the large multi-wire/strand cables of major suspension bridges, it is not very practical for the small cables to be utilized on the new Point Bonita Bridge. However, there are some newer systems being developed for smaller suspension bridges. Freyssinet is a French company that specializes in post-tensioning and stay cable systems. Building on their monostrand technology utilized in cable stay bridges, Freyssinet developed a product called COHESTRAND for use in parabolic suspension systems. COHESTRAND is a 7-wire-strand sheathed by extrusion of specific polymers with an external HDPE coating. Each strand has three layers of protection: galvanized or Galfan-coated wires, a bonded PolyBd filler, and HDPE sheathing. The bond compound is capable of transferring compression and shear forces from the HDPE sheath to the strand itself, making it very suitable for transferring suspender loads to the main cables. The individual strands are placed in parallel bundles to form the main cables. The bundle is also covered with HDPE sheathing. Because the strands are anchored individually, there is no upper limit to the number of strands in a cable. As a result, the system can be used in the largest suspension bridges as well as smaller structures. Each 15.7-mm strand has a breaking strength of about 63,000 lbs.[28]

Unlike traditional cable wraps, where the wrapping is interrupted at the cable bands, the COHESTRAND system is continuous from anchorage to anchorage, providing a much more watertight system. In order to make this possible, a new collar concept utilizing a conical wedge system was developed, which can provide the necessary clamping force without damaging the sheathing. The COHESTRAND system was used on a pedestrian suspension bridge rehabilitation project in the South of France in 1999. The main cables comprise seven bundled strands and the suspenders are made from a single strand.



Example pedestrian bridge utilizing COHESTRAND.

Freyssinet claims the COHESTRAND system provides continuous corrosion protection that can ensure over 100-year durability. However, this durability will come at a significantly greater cost than a traditional cable system. This system also requires the use of proprietary hardware and specialized installers.

Stainless Steel Strand

Stainless steel is a steel alloy with high chromium content. When it's exposed to oxygen, a very thin layer of chromium oxide is formed on the surface. This layer is too thin to be visible, which is why stainless steel remains "shiny," yet is impervious to water and air, protecting the underlying metal from corrosion. When the protective layer is scratched, it quickly forms a new layer. The most common type of corrosion in stainless steel is pitting. Pitting is localized corrosion at individual sites that typically starts at points of weakness in the protective oxide film. The second most common type of corrosion is crevice corrosion. Crevice corrosion occurs at locations where there is a small gap, or crevice, between the stainless steel article and another item. The mechanisms of pitting and crevice corrosion are similar and both most commonly occur in chloride environments (salt water).[29] Stainless steel failures are typically more brittle than regular or galvanized steel. In addition, stainless steel cables are more susceptible to internal corrosion that is not easily detectable.

The existing stainless steel wind cable suspenders were installed on the bridge in 1979 and still appear to be in good condition. There is some rusting near the suspender sockets. This could be a combination of staining due to corrosion of the sockets as well as localized corrosion at the interface between the socket and the cable. While a stainless steel strand should last longer than galvanized steel, it is approximately 3 to 4 times the cost of galvanized strand.

Synthetic Cables

Synthetic cables are gaining popularity in structural applications. For example, they are being used extensively as broadcast and navigational tower guys because they do not create interference in the radio signals. The most common type of synthetic cable is one made of para-aramid fibers. Aromatic polyamides (aramids) were first introduced in commercial applications in the early 1960s with a meta-aramid fiber called Nomex produced by DuPont. In 1973, DuPont developed a para-aramid called Kevlar. Para-aramids have a much higher tensile strength and modulus of elasticity.[30]

The majority of the synthetic structural cables in use today are made of Kevlar. Phillystran is a major U.S. producer of Kevlar Cables. Linear Composites is a British company that manufactures a similar product called Parafil. They each consist of a core of closely packed, high-strength para-aramid fibers, lying parallel to each other, encased in a tough and durable polymeric sheath. These cables do not corrode or degrade when exposed to saltwater and the sheathing provides UV protection. Parafil cables were used for the main cable stays on a footbridge constructed in 1992 over the River Tay in Aberfeldy, Scottland. E.T. Techtonics has used Kevlar cables to prestress FRP king-post and queen-post truss pedestrian bridges, and supplied the FRP truss bridges along the Point Bonita trail. However, these bridges are traditional truss bridges without prestressing cables. Carbon Fiber Reinforced Polymer (CFRP) cables are also being used experimentally on cable stayed bridges.

The use of synthetic cables for cable-supported bridges is still in the experimental stage and has been primarily limited to cable-stayed bridges, not suspension bridges. While this technology has great potential, its use in the Point Bonita Bridge would be very expensive and require a specialty contractor. It would also require special inspections and would be very difficult to modify or repair.

Suspenders

All of the materials described above for the main cables could also be utilized for the suspenders, with the exception of galvanized wire strand (galvanized wire rope would be a more likely choice). In addition, the suspenders could also be constructed of solid materials. The existing bridge suspenders are 7/8-inch–diameter galvanized steel rods.

Wind Bracing System

The wind bracing system is very similar to the main cable system and should be constructed of similar materials.

Towers

Treated Wood

Attempts have been made to protect and preserve wood for thousands of years. The ancient Greeks soaked wood in olive oil and the Romans brushed their ship hulls with tar. As early as the early eighteenth century, Europeans were experimenting with chemical solutions of mercury chloride. The first patent for pressure treating, a process which involved injecting creosote into wood under considerable pressure, was granted in 1838.[31]

Pentachlorophenol (Penta), an oil-borne preservative, and chromated copper arsenate (CCA), a waterborne preservative, came on the scene sometime around World War II. By the 1960s, with the increased demand for consumer related wood products like picnic tables and exterior decks, CCA become the treatment of choice.

Over the last decade concerns have been raised about the safety of CCA-treated wood, due to its arsenic content. Arsenic is a toxin that can cause a wide range of adverse health effects at low and high doses. In 2002, the U.S. Consumer Product Safety Commission issued a report stating that exposure to arsenic from direct human contact with CCA treated wood may be higher than was previously thought. In 2004, the Environmental Protection Agency (EPA) and the treated wood industry agreed to voluntarily restrict the use of CCA-treated wood in residential and commercial construction with a few exceptions. Some exceptions include highway construction, marine (saltwater) applications, utility poles, pilings, and selected engineered wood products.[32] Ammoniacal copper zinc arsenate (ACZA) is another preservative similar to CCA that is often used on difficult to treat wood such as Douglas-fir.

In recent years, newer water-borne preservatives have been developed as alternatives to CCA and ACZA. The most common treatment used today is alkaline copper quaternary (ACQ). ACQ is a preservative made up of copper, a fungicide, and a quaternary ammonium compound, an insecticide which also augments the fungicidal treatment. Copper azole, sometimes formulated as copper boron azole, is the other major copper based wood preservative that has come into wide use in the U.S., Europe, Japan, and Australia. Neither of these types of treated wood is approved for saltwater applications.[33]

The Pacific West Region of the National Park Service has developed a guidance document containing a list of 100-plus best management practices to define what a green park looks like. This document recommends not using wood with hazardous chemicals, particularly arsenic and chromium. Where treated wood is required, it recommends using ACQ, copper naphthenate (oil-borne preservative) or copper boron azole instead. To go even further, the Presidio Trust in San Francisco, which works with the Golden Gate National Parks Conservancy, has completely banned the use of lumber treated with CCA, ACZA, pentachlorophenol and other similar chemicals.

CCA, ACZA and creosote are still the only common wood preservatives that are approved for saltwater use. Creosote-treated wood is messy and non-paintable. CCA and ACZA are paintable, particularly after seasoning, and are the most economical wood treatments. Painting also reduces the environmental risks associated with these preservatives. However, the GGNRA would need to weigh the benefits versus the risks in determining if CCA or ACZA treated wood is a viable alternative.

Native Woods

There are a few native woods, including Redwood and Western Red Cedar, that are often used for outdoor and marine structures as an alternative to pressure treated wood. Both of these species are softwoods that contain tannins and oils that make them naturally resistant to rot, decay, and voracious insects. However, the level of weather- and bug-resistance is directly related to the amount of heartwood in the boards. Heartwood grows closer to the center of the tree and is relatively hard and very resistant to decay. Sapwood grows in the outer part of the tree, near the bark, and is softer and more susceptible to decay.

Tropical Hardwoods

Tropical hardwoods are also used for outdoor and marine structures. While more expensive, these woods are naturally resistant to rot and decay and some are also resistant to marine borers, which are a concern for wood that is placed below the water line. Tropical hardwoods are typically very dense, with unit weights up to 75 pcf. The most common hardwoods are imported from Central and South America as well as Western Africa. Unfortunately, these trees are often harvested illegally and irresponsibly. Environmental and social activists argue that using them contributes to deforestation of the Amazon River basin and other natural forests, ill effects on the air we breathe, global climate change, and the use of slave labor for harvesting.

Thus, using tropical hardwoods can be complicated. The 2008 Farm Bill included legislation that amends the U.S. Lacey Act, a longstanding wildlife trafficking statute, to include a ban on the import of illegally harvested wood. This new legislation will go a long way towards ensuring that only timber that has been harvested responsibly and legally makes it into the U.S. market. Another way to guarantee this is to use only products that have been certified to come from legal and responsible sources. The Forest Stewardship Council (FSC) is one example of an international agency that provides this certification. The NPS best management practices guidelines recommend not using tropical hardwoods unless it is reliably documented that the wood is from well-managed forests. The section below describes tropical hardwoods are most commonly used in marine construction.

Greenheart is a tropical hardwood that is primarily found in the rain forests of Guyana, in Northern South America. It has been harvested as commercial timber since the late 1700s and is used primarily in marine and ship construction, with extensive use in marine piling. Heartwood varies from light to dark olive green or blackish. The texture is fine and uniform and the grain is straight to interlocked. The wood dries very slowly, with a marked tendency to check and end split with a volumetric shrinkage of 17 percent. It is moderately difficult to work using hand or machine tools. The heartwood is rated highly resistant to attack by decay fungi and is also rated as highly resistant to attacks by marine borers and dry-wood termites.[34]

Ekki, also known as Azobe, is tropical/subtropical hardwood found in Western Africa and the Congo Basin. It is used in marine construction, heavy duty flooring/decking and for railroad ties. Heartwood is dark red, chocolate brown, or purple brown with white deposits in the vessels. The texture is coarse and the grain is usually interlocked. It dries slowly and is very difficult to season without excessive degrade, particularly surface and end checking, with a volumetric shrinkage of 17 percent. It is very difficult to work with hand and machine tools. The heartwood is rated as very durable but only moderately resistant to termite attack. It has good weathering properties.[35]

Ipê, also known as ironwood, is a tropical hardwood that is found in Brazil and tropical South-Central America. It is used in marine construction, heavy-duty boardwalk decking/flooring, and in railroad ties. Heartwood is olive brown to blackish often with lighter or darker striping. The texture is fine to medium and the grain is straight to very irregular. It air-dries rapidly, with only slight checking and warping and a volumetric shrinkage of 13 percent. It is moderately difficult to work with hand tools. The heartwood is very resistant to decay fungi and termites, but is not resistant to marine borers. This wood is commonly used for pedestrian bridges in the United States and is readily available.[36]

Tropical hardwoods are by far the most durable wood, lasting as much as three to five times longer than native and pressure treated woods. While tropical hardwood can be painted, it is normally left unfinished. The material cost of tropical hardwood is approximately two to three times as expensive as pressure treated wood.

Plastic-Coated Wood

While plastic-coated wood has been around for decades, only in recent years has it gained popularity in marine and coastal construction. One of the earliest and most common uses of plastic coated wood is for marine piles, as the plastic coating provides a barrier against penetration by marine borers. Plastic coated wood is being used more and more in other outdoor environments, from piers, docks, and marine bulkheads to retaining wall systems, decks, and patios. Timbers and lumber can be custom cut to their finished dimensions by the manufacturer before coating, eliminating the need for any additional cutting and field coating. Field patch kits are available if any cutting is required in the field. The coating can be applied to untreated wood, but is more often applied to pressure treated wood, which makes the wood much safer for the environment because the plastic coating prevents the chemicals in the wood from leaching out.

Cross section of 21Poly coated Wood.

Unfortunately, there are only a limited number of manufacturers that produce plastic coated wood. 21POLY, one of the more common coating systems, was developed by the Northstar company. 21POLY uses a patented spray process that bonds a protective polymer layer to pressure treated wood. According to the company's literature, the system has been used by the U.S. Army Corps of Engineers, the National Park Service, the U.S. Fish & Wildlife Service, and the San Francisco Harbor and Port Authority. It is applied by a licensed applicant, usually the same company that treats the wood. Some applicants have mobile applicators that can apply the product on site.

One of the primary issues associated with using plastic coated wood is that it is not easy to inspect the underlying wood for signs of rot. Also, bolted connections need to be sealed to prevent water from entering the uncoated wood. However, the pressure treated wood underneath the plastic coating provides good level of protection for what little water may seep in around bolted connections. Is may also be possible to drill all of the required holes prior to coating and then coat everything, including the bolt holes.

Plastic Lumber

Most plastic lumber products on the market are made from polyethylene. Some manufacturers are also using polystyrene and polyvinyl chloride (PVC), and others rely on a mix of different types of plastics, typically collected from municipal recycling programs. Recycled content varies widely among plastic lumber products. Roughly one half of the products available today contain post-consumer and/or post-industrial materials.

Another form of plastic lumber is wood/plastic composite lumber (WPC). WPC is made from a 50/50 mix of plastic resin and wood flour or wood fibers. TREX is a common example of a WPC. Recycled plastic bags and sawdust from manufacturing plants are common material sources for recycled WPC. Although the word "composite" may lead one to believe that the material is stronger, WPC is not necessarily stronger than other plastic woods. The primary reason for using wood fibers is to keep the cost down: If the board were made entirely of plastic, it would be much more expensive. WPC is designed to completely encapsulate the wood fiber in plastic, but in many cases wood fibers are exposed, which can lead to staining and mold growth. For our bridge, staining from bird droppings is a big concern.

The primary issue with pure plastic lumber and wood/plastic composite lumber is that they are not particularly suitable for structural applications. They are not very stiff and have a tendency to creep under sustained loads and are typically used only for decking, where they require more closely spaced supports than natural wood boards.

Example vehicular bridge made from structural grade plastic lumber.

Another option might be structural grade plastic lumber, which is plastic lumber that's been reinforced with other materials, such as fiberglass and polystyrene. Structural grade plastic lumber is a high-performance timber product that is extremely suitable for marine construction. It has exceptional resistance to marine borers, salt spray, fungi, and other environmental stresses. It does not absorb moisture, so it can't rot, splinter, or crack. Structural plastic lumber is produced in a wide range of dimensional lumber and timber sizes. It can be fabricated and installed with the same tools used for traditional wood construction. A wide range of colors is available, including white. Other than occasional washing, plastic lumber requires no painting or long term maintenance. While structural grade plastic lumber is substantially stronger and has a higher modulus of elasticity than plain plastic or WPC lumber, it still has structural properties that are slightly lower than wood. As a result, some members may need to be a little larger than the size required for traditional wood.

Environmentally, structural grade plastic lumber is preferable to pressure treated lumber. There are no chemicals that can leach out to contaminate water and soil or be harmful to humans, and a significant amount of the plastics used in structural lumber is recycled, keeping that material out of landfills. Structural grade plastic lumber is also not reactive with metal fasteners, whereas pressure treated wood can accelerate fastener corrosion. However, because of the material's fiberglass content, precautions are necessary during manufacturing, working, and machining to prevent workers from inhaling fibers.

Trimax, produced by Trimax Building Products, is a commercially available structural grade plastic lumber. Trimax is made of a patented formula of 100 percent recycled plastic (HDPE)—the type found in everyday recyclable products such as milk jugs and detergent bottles—and a fiberglass strengthener called fiberfill. Trimax also includes an ultraviolet stabilizer to prevent breakdown from the sun. Other products similar to Trimax include FiberForce by Bedford Technology and PolyForce by Tangent Technologies. Most manufacturers warrant their products will not rot, splinter, decay, or suffer structural damage directly from termites, marine borers, or fungal decay under normal use for 25 to 50 years.

FRP Structural Shapes and Plates


FRP pedestrian truss bridge being erected.

Pultruded Fiber-Reinforced Polymer (FRP) shapes are gaining popularity in bridge construction, particularly in pedestrian bridges. In fact, the two small truss pedestrian bridges along the Point Bonita access trail are made of pultruded FRP shapes. Pultrusion is a manufacturing process for producing continuous lengths of FRP structural shapes with constant cross sections. The raw materials are a liquid resin mixture and flexible textile reinforcing fibers, which are pulled through a heated steel forming die using a continuous pulling device. Shapes typically have a surface veil to keep glass fibers from penetrating the resin surface in service and to increase corrosion and UV resistance.

A wide range of shapes and sizes is available, including angles, channels, I-beams, wide flange beams, plates, round tubes, rectangular tubes, and square tubes as well as square and round bars. Custom colors are available, but stocked shapes are only available in two or three colors. FRP shapes can also be primed and painted, which will increase UV protection and the life of the material and is recommended in severe environments. Connections are typically made with mechanical fasteners, but in marine environments, stainless steel bolts are recommended. Since it is not possible to bend or weld FRP, all sections, joints, and connections have to be made, for the most part, from a combination of standards shapes, plates, and bolts.

FRP shapes are significantly lighter than almost any other building material. As a result, the individual members can easily be carried by one or two people, making it easier to erect the bridge in a remote location like Point Bonita. Shapes made of FRP are also extremely durable in harsh environments. FRP is more flexible and designs are typically controlled by deflection rather than strength, and, under sustained loads, FRP shapes continue to deflect or creep. However, FRP is more easily damaged than other materials, and over-tightening of bolts can crack it. The material costs for FRP shapes are about the same as equivalent steel shapes and about twice as much as pressure treated wood.

Structural Steel

Structural steel is a common material for structures such as the towers of this suspension bridge. Steel is strong, durable, easy to erect, and cost effective. A-shaped steel towers could be constructed of angles, channels, and wide flange members and would aesthetically match the historic period of the site but would not look at all like the timber towers of the existing bridge.

Although the steel components of the existing bridge performed poorly in the salt-laden marine environment at Point Bonita, a modern galvanizing/coating/painting system could provide better protection and ensure long service life.

Instead of completely replicating the existing bridge towers, a more cost-effective solution would be to construct the towers with vertical column legs and a simple cross member at the top. These slender tower legs would be no-moment pinned struts, held in place by the suspension cables and back spans. This is a common configuration for pedestrian suspension bridges.

Example vertical steel tower.

Stiffening Truss

Any of the materials described above for the towers could also be utilized for the stiffening truss. However, the material chosen should be visually compatible with the towers. For example, a stiffening truss made of structural steel would look out of place with timber towers, whereas a stiffening truss made of FRP shapes would look fine with towers made of structural steel.

Deck

While all of the materials described for the towers could also be utilized for the deck, pressure treated wood, tropical hardwood, plastic coated wood, or plastic lumber would be more suitable. Decks made of structural steel or FRP would need to be more of a grating type of decking, resulting in a more industrial look.

Miscellaneous Hardware

The miscellaneous hardware will be determined based on the selected materials for the cables, towers, and stiffening truss. Cables systems need specialized connection hardware. Structural steel towers or trusses would be simply welded and bolted. Timber members would be attached with steel connection hardware and bolts. All miscellaneous hardware will be selected to perform as well as the main building materials of the bridge. All hardware would be galvanized and painted as appropriate.

SUMMARY OF RECOMMENDATIONS

The following recommendations are based on our discussions with the National Park Service, a project site reconnaissance, review of the original design drawings and retrofit drawings, materials review and research, and conceptual level analysis of the structure. The replacement structure should:

- Provide long service life with minimum maintenance in this harsh marine environment,
- Respect the historic nature of the site and look similar to the existing bridge, with A-shaped white towers,
- Be attractive,
- Be easy to construct considering the limited site access, and
- Be reasonably cost effective.

The recommended replacement bridge will have a nearly identical look as the existing bridge. The new suspension bridge will be on the same alignment as the existing bridge, have A-shaped, painted timber (tropical hardwood) towers, be 4 ½ feet wide, and have a timber stiffening truss. The recommended material for each component of the proposed structure is listed in Table A on the following page.

COST EVALUATION

The cost of the proposed bridge is largely set by the following factors:

- The criteria to replicate the look of the existing suspension bridge,
- The need for durability in the harsh marine environment, and
- Very difficult site access.

The impacts of material section on cost are qualitatively noted in Table A. The estimated cost of the proposed bridge is detailed in Appendix B. The estimated cost assumes free and open bidding. The cost shown is an estimate of the low bid and does not include engineering or construction management and inspection.

TABLE A – PROPOSED COMPONENT MATERIALS

Component	Recommended	Material	Pros	Cons	Cost Relative to Baseline
Main Suspension Cables	Yes	Structural strand w/high-performance wire coating (galvanized or galfanised); consider overcoating w/high-performance paint	Well-established, proven performance	Existing bridge deteriorated in harsh marine environment, but better coatings are now available	Base cost
	No	Stainless steel	Very corrosion resistant	Not commonly used for primary structural components; prone to internal pitting; not as ductile as conventional strand.	Material cost 3 to 4 times greater than base cost
	No	Synthetic	Very corrosion resistant	Still experimental for primary structural components; not ductile.	Greater material cost; requires specialty contractor
Suspender Cables	Yes	Structural rope w/high performance wire coating (galvanized or galfanised); consider overcoating w/high-performance paint	Same as main cables	Same as main cables	Base cost
Wind Cables	Yes	Same as main cables	Same as main cables	Same as main cables	Base cost

Component	Recommended	Material	Pros	Cons	Cost Relative to Baseline
Towers	Yes	Tropical hardwood painted white	Identical look as existing bridge; very durable with low maintenance	Concerns with environmental sustainability can be mitigated with appropriate certification; not domestically available	Base cost
	No	Treated timber	Domestically available; easy to work with	Not as durable as tropical hardwood; concerns with pressure treatment chemicals	Material costs 2 to 3 times less than base cost
	No	Native woods (untreated)	Naturally resistant to rot, decay, and insects	Not durable enough for consideration	Less expensive than base cost
	No	Plastic-coated wood	Resistant to rot, decay, and insects	Appearance not genuine; not possible to inspect wood	Similar to base cost
	No	Plastic lumber	Very durable	Appearance not genuine; low stiffness	Similar to base cost
	No	FRP structural plates and shapes	Very durable	Appearance not genuine; difficult to work with; not the same look as the existing bridge	Similar to base cost
	No	Structural steel, galvanized and painted	Similar durability to the baseline with continued maintenance.	Not the same look as the existing bridge	Similar to base cost
Stiffening Truss	Yes	Same as towers	Same as towers	Same as towers	Base cost

Component	Recommended	Material	Pros	Cons	Cost Relative to Baseline
Deck	Yes	Wood type to match towers	Authentic look to match towers. Durability to match towers.	Could be more expensive than plastic lumber	Base cost
	No	Plastic lumber	Very durable	Appearance not genuine	Similar to base cost
Misc. Hardware	Yes	Structural steel, galvanized and painted	Durability to match main components	None	Base cost
Anchorage Blocks	Yes	Concrete gravity blocks	Conceptually simple; limited geotechnical investigation needed	Difficult and costly to remove existing foundations	Base cost
	No	Reuse existing anchorage blocks. Use rock anchors to hold down blocks for increased capacity	Don't require removal of existing anchorages	Anchorages have already been modified once; would need to carefully evaluate rock characteristics at site	Similar to base cost
Pier Foundations	Yes	Reuse existing foundations	No cost	This would be the only remaining component of the existing bridge.	Base cost

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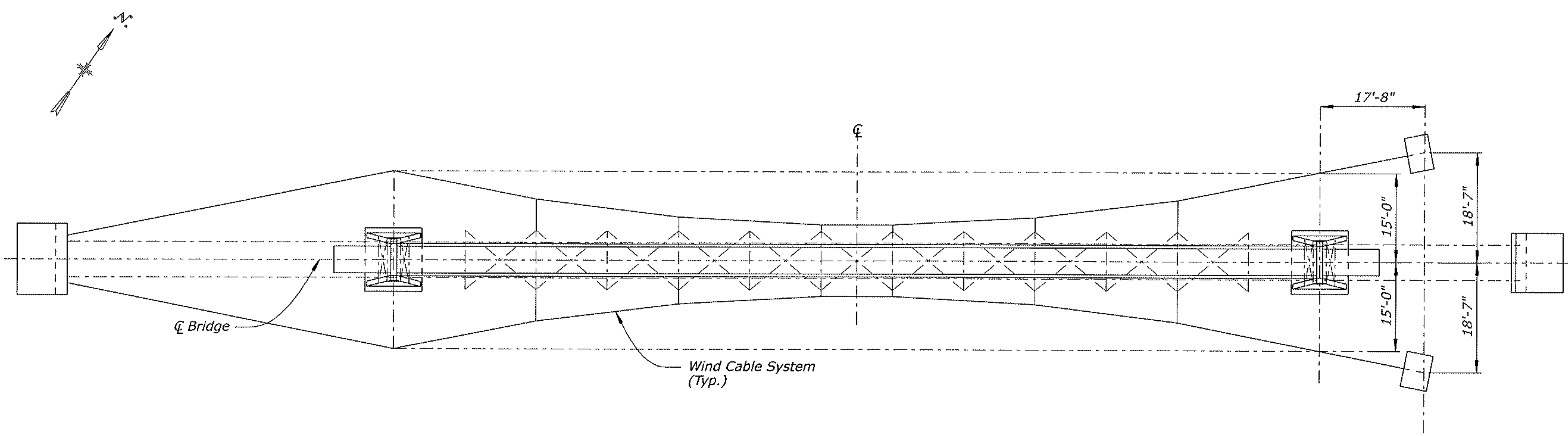
APPENDIX B - FIGURES

LOCATION MAP

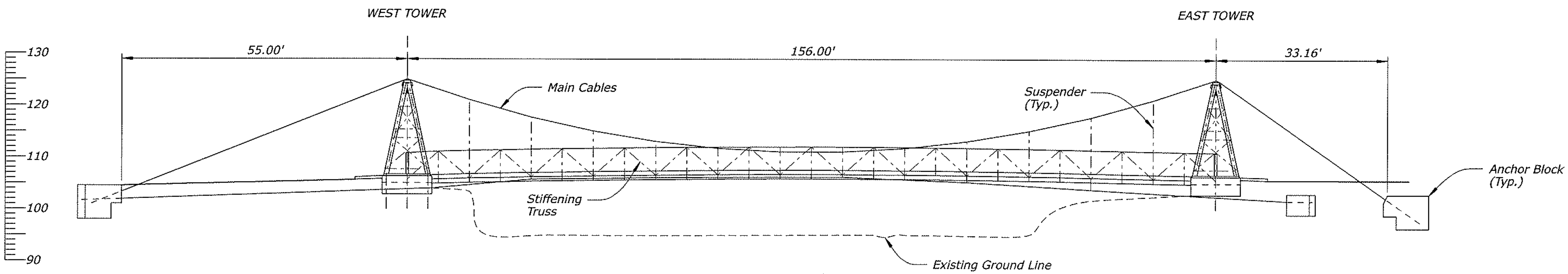

PARKING AND
STAGING AREA
TRAIL
HEAD
TURNAROUND
TUNNEL
EXISTING
BRIDGE
STAGING
AREA
POINT BONITA
LIGHTHOUSE

SITE PLAN

REGION	STATE	PROJECT	SHEET NO.	TOTAL SHEETS
	CA	NPS GOGA 433 (I)		



PLAN



ELEVATION

BRIDGE DRAWING INDEX

PRELIMINARY
NOT FOR CONSTRUCTION

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
CENTRAL FEDERAL LANDS HIGHWAY DIVISION

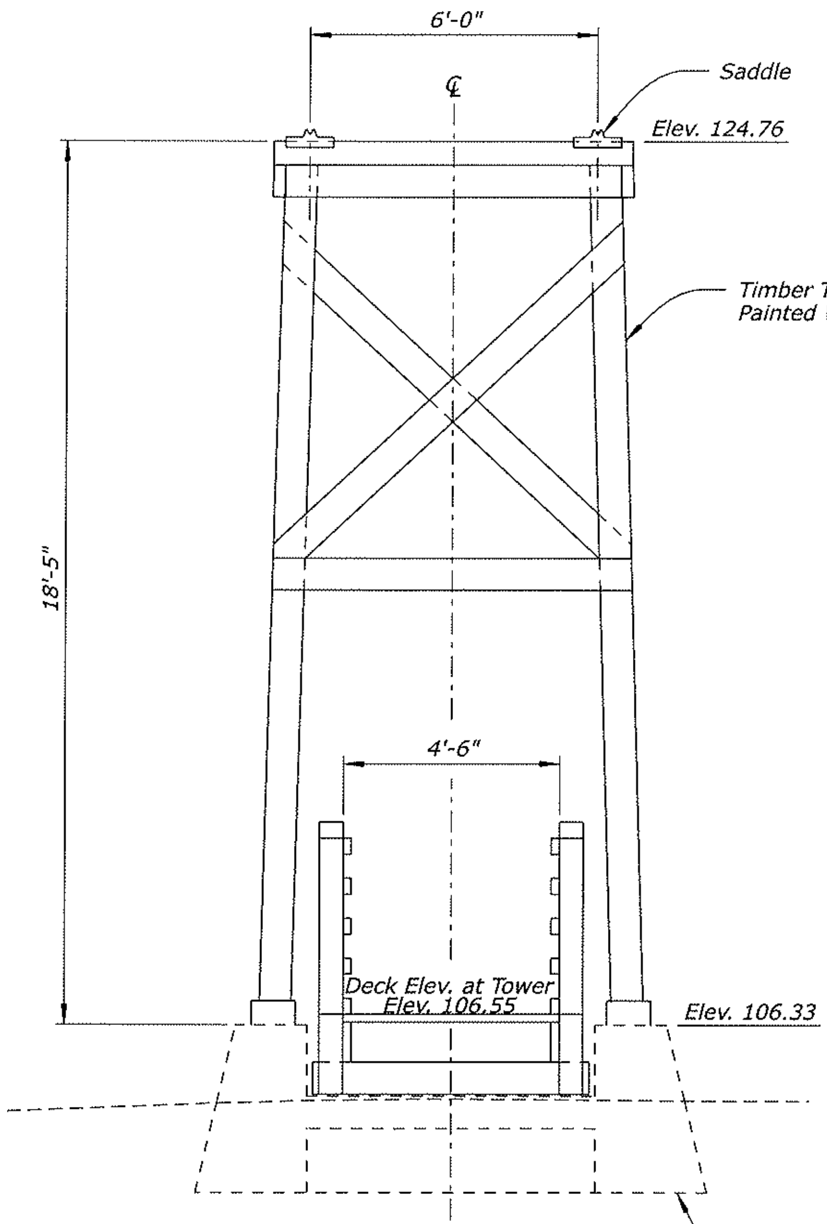
POINT BONITA BRIDGE

PLAN AND ELEVATION

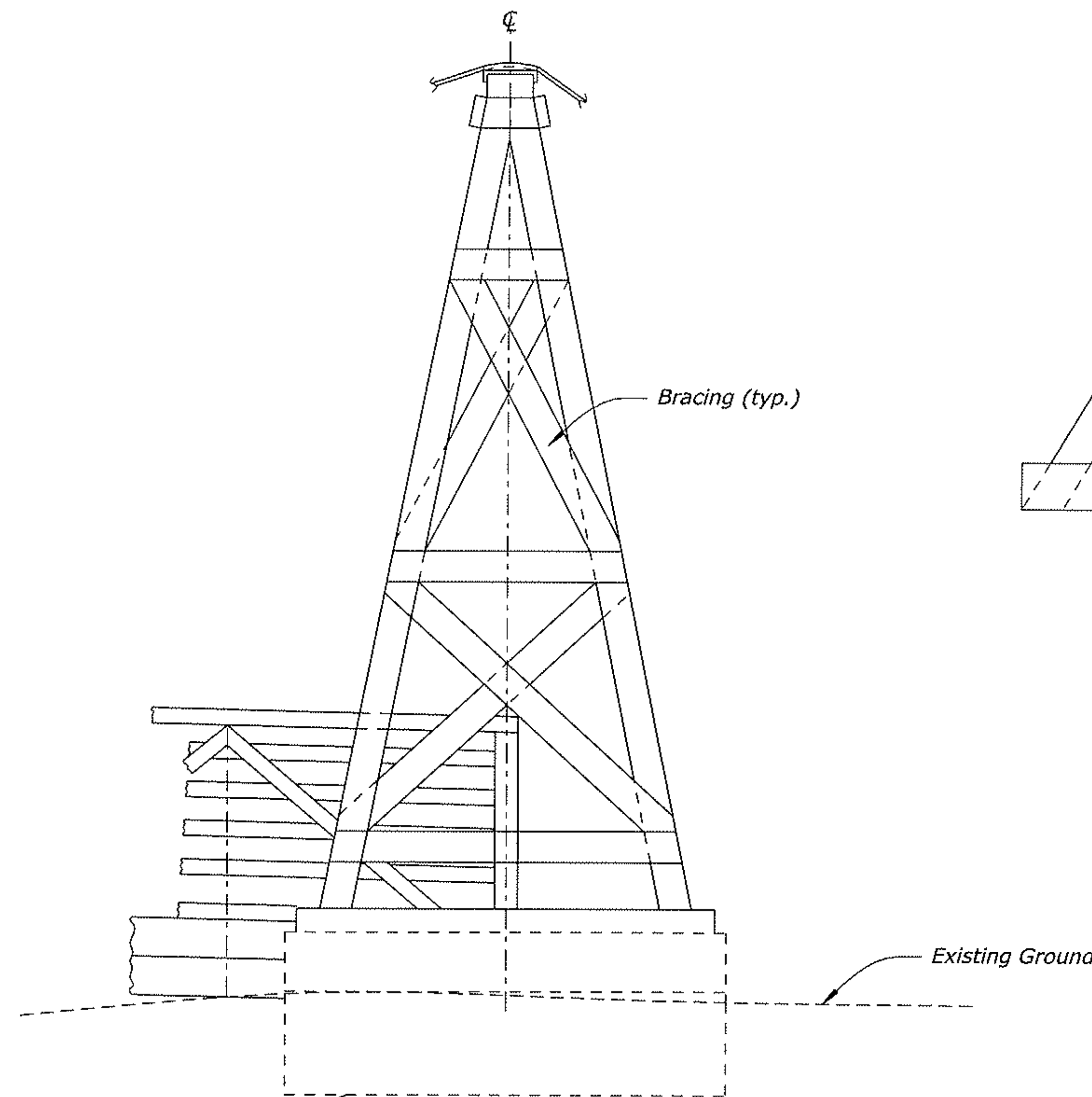
NO.	DATE	BY	REVISIONS	NO.	DATE	BY	REVISIONS

DESIGNED BY	DRAWN BY	CHECKED BY	SCALE	PROJECT TEAM LEADER	BRIDGE DRAWING	DATE	DRAWING NO.
JMB	OR		1" = 10'-0" UNLESS NOTED		of	01-30-09	RG2858-A

REGION	STATE	PROJECT	SHEET NO.	TOTAL SHEETS
	CA	NPS GOGA 433 (1)		

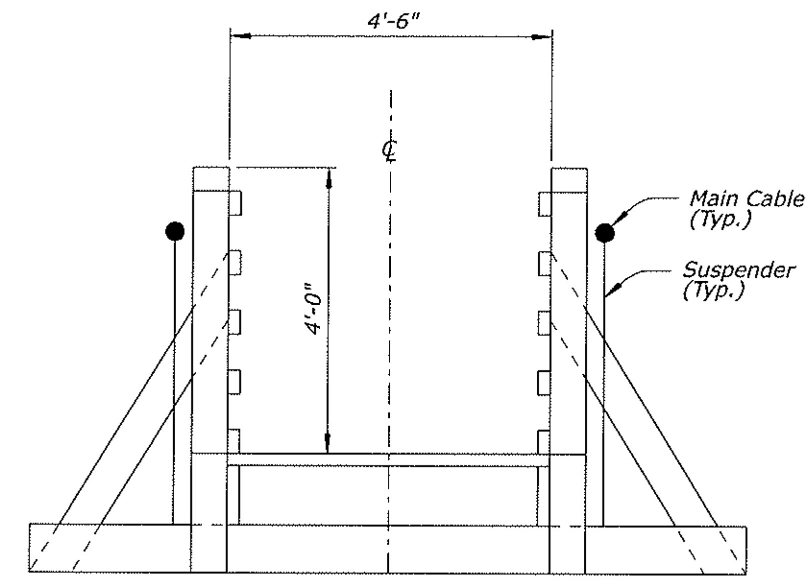


PORTAL DETAIL AT TOWER



Existing Tower Foundation

SIDE ELEVATION OF TOWER



SECTION OF WALK

PRELIMINARY
NOT FOR CONSTRUCTION

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
CENTRAL FEDERAL LANDS HIGHWAY DIVISION

POINT BONITA BRIDGE

TOWER AND DECK SECTION

NO.	DATE	BY	REVISIONS	NO.	DATE	BY	REVISIONS	DESIGNED BY	DRAWN BY	CHECKED BY	SCALE	PROJECT TEAM LEADER	BRIDGE DRAWING	DATE	DRAWING NO.
								JMB	OR		1" = 10'-0" UNLESS NOTED		of	01-30-09	RG2858-B

Monday, February 02, 2009 10:14:29 AM C:\PWworking\OMA\d0345259\RG2858-B.dgn

APPENDIX C - COST ESTIMATE

3/20/2009

ONE COMPANY
Many Solutions

Concept Level Cost Estimate
Point Bonita Lighthouse Bridge - RG 2858
FHWA Project - CA NPS GOGA 433(1)

CREATED BY: DFC
CHECKED BY: JMB

DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	COST
Mobilization	LPSM	1	$ 50,000.00	$ 50,000
Construction Surveying and Staking	LPSM	1	$ 10,000.00	$ 10,000
Removal of Bridge (existing bridge above ground)	LPSM	1	$ 65,000.00	$ 65,000
Removal of Structures and Obstructions (anchorage blocks)	CUYD	33	$ 500.00	$ 16,500
Structure Excavation (for enlarged anchorage blocks)	CUYD	41	$ 200.00	$ 8,200
Structural Concrete (new anchorage blocks)	CUYD	74	$ 1,500.00	$ 111,000
Timber (tower) FOB	B-FT	1649	$ 15.00	$ 24,735
Timber (truss) FOB	B-FT	4202	$ 15.00	$ 63,030
Timber (deck) FOB	B-FT	1404	$ 15.00	$ 21,060
Timber Connection Hardware (FOB)	LPSM	1	$ 15,000.00	$ 15,000
Main Cables, 1 1/2 Inch Galv. Structural Strand w/ Sockets (FOB)	LPSM	1	$ 45,000.00	$ 45,000
Main Cable Saddles (FOB)	LPSM	1	$ 17,000.00	$ 17,000
Main Cable Clamps (FOB)	LPSM	1	$ 12,000.00	$ 12,000
Main Cable Suspenders, 3/4 Inch Galv. (FOB)	LPSM	1	$ 34,000.00	$ 34,000
Wind Cables, 1 1/2 Inch Galv. (FOB)	LPSM	1	$ 48,000.00	$ 48,000
Wind Cable Clamps (FOB)	LPSM	1	$ 6,000.00	$ 6,000
Wind Cable Boom Tip Saddles (FOB)	LPSM	1	$ 9,000.00	$ 9,000
Wind Cable Suspenders, 3/4 Inch Galv. (FOB)	LPSM	1	$ 17,000.00	$ 17,000
Bridge Erection	LPSM	1	$ 150,000.00	$ 150,000
Paint Bridge	LPSM	1	$ 35,000.00	$ 35,000
Remove and Replace Communication Line	LPSM	1	$ 10,000.00	$ 10,000
Remove and Replace Existing Power Line	LPSM	1	$ 10,000.00	$ 10,000
Miscellaneous Site Work as Directed	LPSM	1	$ 50,000.00	$ 50,000
Contingency	LPSM	1	$ 250,000.00	$ 250,000
				$ 1,077,525